

JOURNAL OF THE ANTHROPOLOGICAL SOCIETY OF SOUTH AUSTRALIA

Special Edition
Issues in South Australian Aboriginal Archaeology

VOLUME 34 – JUNE 2011

EDITORS
Amy Roberts and Keryn Walshe

JOURNAL OF THE ANTHROPOLOGICAL SOCIETY OF SOUTH AUSTRALIA

ARCHAEOLOGICAL INVESTIGATIONS AT OLYMPIC DAM IN ARID NORTHEAST SOUTH AUSTRALIA

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Archaeological Investigations 1980-2007: Development of a Predictive Model

This is an outline of a large ongoing research-oriented salvage program that has evolved from past archaeological impact assessment studies at Olympic Dam in arid northeast South Australia.

In 1980 Hughes, Hiscock and colleagues commenced a range of archaeological investigations for the proposed Olympic Dam mining project (Figure 1), the findings of which were presented in the 1982 Draft EIS (Kinhill-Stearns Roger 1982:Chapter 5; see also Hughes and Sullivan 1984 for a summary of the model). In the course of these investigations Hughes and Hiscock developed an environmentally-based predictive model described in that Draft EIS that used terrain pattern mapping based on a combination of landform types and underlying geology. Landform types were used to predict the location and frequency of occurrence of suitable 'campsites', sources of water and the ease with which people could move across the landscape. Geology was used to predict the availability of different rock types which could be used for making stone artefacts.

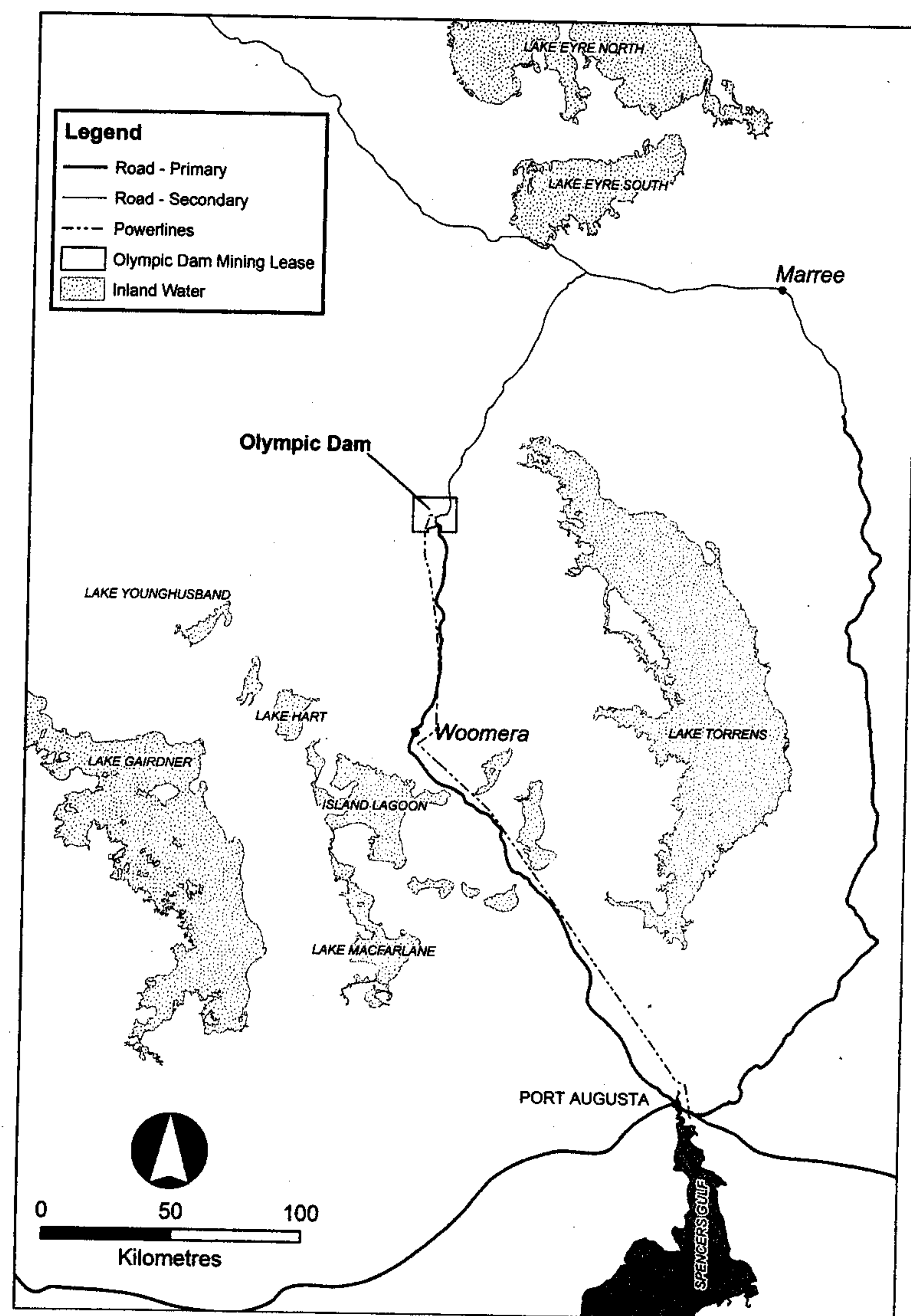


Figure 1 The location of the Olympic Dam project (prepared by BHPB Nickel West Land Services, Perth).

Initially data from 133 archaeological sites and their environmental settings were used to develop and test the predictive statement (Kinhill-Stearns Roger 1982:Section 5.1.3 and 5.1.4, Tables 5.2 and 5.3). The model was then tested further using data from an additional 352 archaeological sites recorded in sample surveys at Olympic Dam and in a regional survey within a 50km radius of Olympic Dam. An analysis of data collected from these surveys strengthened the conclusion that there was a direct correlation between the results of these EIS surveys and the predictive statement (Kinhill-Stearns Roger 1982:5-23). The predictive model originally developed in the 1980s is summarised in Table 1. The geological regime component of the model presented in Table 2 is based on our current improved knowledge of the surface geology, as the original mapping was based on air photograph interpretation with very limited ground survey.

Over the subsequent years to the beginning of 2007 further survey and limited salvage work was undertaken intermittently for various stages of the development of the mine. As well as surveys at the mine site, these included surveys for electricity transmission lines from Port Augusta and water supply pipelines from the Great Artesian Basin in the vicinity of Lake Eyre South. In the course of these surveys another 336 archaeological sites were recorded, bringing the total to about 820 sites.

An analysis of the combined archaeological data gathered up to 1997 confirmed and strengthened the applicability of the archaeological predictive model first produced for the 1982 Draft EIS in the region extending from Spencer Gulf in the south to Lake Eyre in the north (Figure 1), a linear distance of about 450km (Kinhill 1997:6-7), and the model was established as a useful tool for guiding further survey work or for projecting likely impacts from development.

Table 1 Predicted influence of landforms on the nature and distribution of archaeological sites (based on Kinhill-Stearns Roger 1982:Table 5.6).

Landform Type	Model Prediction
1 and 2 Tableland and Tableland with dissection slopes	Sites occur infrequently in these landform types and when they do they are mainly quarries and knapping floors where locally available raw materials have been exploited. The quarry sites are commonly very large ($>1,000\text{m}^2$) and have high density artefact scatters ($1-10/\text{m}^2$) of the only locally available raw material. Where isolated dunes occur within these landform types they generally contain rich, diverse artefact scatters.
3 Drainage depressions	While archaeological sites occur infrequently in this landform type, they occur mainly on sand dunes around the margins of the large moisture-holding depressions which characterise this landform type. The sites tend to be very large and to have very high densities of artefacts ($>10/\text{m}^2$). There is also a very high diversity of raw material types and a wide range of implement types. This combination of characteristics indicates that the drainage depressions and their associated dunes acted as focal points for occupation and supported a wide range of domestic activities.
4 Widely spaced dunes covering $<30\%$ of the land surface	Sites in this landform type are generally medium to large ($10-1,000\text{m}^2$) and have medium to high densities of artefacts ($0.1-10/\text{m}^2$) which include a range of implement types. Artefacts are made from a low to medium diversity of raw materials. Most sites are artefact scatters on sand dunes and tend to be concentrated around the interdunal pans. In terrain patterns formed on K, A and P sites occur with low to medium frequencies. In contrast on Czs, where silcrete crops out most frequently, quarry sites and associated knapping floors also occur and the frequency of occurrence of sites is very high. Compared with landform types 1, 2 and 3, sites in landform type 4 are more evenly dispersed across the landscape. Artefact scatters occur more frequently, are richer and are more diverse on those sand dunes which are adjacent to pans. In contrast, sites in dunes adjacent to quarries (especially silcrete) tend to consist of knapping floors with a low diversity of raw material. The richest sites in this landform type are to be found in dunes adjacent to areas where pans and silcrete quarries occur in close proximity.

Table 1 (cont.) Predicted influence of landforms on the nature and distribution of archaeological sites (based on Kinhill-Stearns Roger 1982:Table 5.6).

Landform Type	Model Prediction
5 Moderately spaced dunes covering 30-60% of the land surface	The nature and distribution of sites in this landform type follow the same pattern as that for landform type 4 except that sites occur much less frequently and tend to be less rich. This is taken to reflect the less common occurrence of pans and outcrops of raw material, due in part to the increased cover of sand.
6 Closely spaced dunes covering $>60\%$ and usually $>80\%$ of the land surface	Sites occur very infrequently in this landform type, because of the almost continuous cover of sand, the absence of surface water and stone sources, and the practical difficulty in traversing these landscapes.

- Frequency of sites in each terrain pattern is based on the following ordinal scale: very low, low, medium, high, very high.
- Size of sites: low ($<10\text{ m}^2$), medium ($10-99\text{ m}^2$), large ($100-999\text{ m}^2$), very large ($1,000\text{ m}^2$ or greater).
- Density of artefacts: low ($<0.1/\text{m}^2$), medium ($0.1-1/\text{m}^2$), high ($1-10/\text{m}^2$), very high ($>10/\text{m}^2$).

Table 2 Predicted influence of geological regime on availability of raw materials for stone artefact manufacture.

Geological Regime		Description	Materials for Artefact Manufacture
Q	Quaternary	Aeolian sand dune fields and clay pans	No materials exposed
Czs	Tertiary	Silicified sandy beach ridges of ancient lake to the west	The main source of silcrete
K	Cretaceous	Deeply weathered kaolinitic siltstones, shales and sandstones (Bulldog Shale) – contains extensive deposits of ice-rafted pebbles, cobbles and boulders, predominantly quartzite	The main source of quartzite – some chert and quartz from the ice-rafted rocks – some silcrete from silicified weathered sediments
A	Cambrian	Andamooka Limestone	Main source of chert
P	Precambrian	Simmens Member of the Arcoona Quartzite	Not suitable for flaking but possible source for grinding stone and hearthstones

Archaeological Investigations for the Proposed Expansion of the Mine

The Olympic Dam Agreement

In 2009 BHP Billiton submitted for government consideration its Environmental Impact Statement for the proposed expansion of the Olympic Dam mine (ARUP/ENSR 2009). The EIS describes the Olympic Dam Agreement reached between BHP Billiton and the Barngala, Kokotha and Kuyani native title claimant groups. In the Olympic Dam Agreement there is a Heritage Management Protocol (HMP) which in part specifies a range of archaeological investigations designed to mitigate the impact of the expansion to be carried out in the 600km² area within which most of the development will occur (referred to as the Application Area):

- Field survey work to record data on archaeological sites in areas not already surveyed (not all of which would be impacted);
- Salvage work on a selection of archaeological sites which have special scientific value; and
- Identifying a similar suite of sites outside the Application Area with similar values that would be protected in the long term.

These archaeological investigations are being carried out as a combined mitigation and research program by HEH and archaeologists from the Australian National University over a seven year period which commenced in 2007 and ends in 2013. In this paper we describe aspects of the survey and salvage stages of the study.

Survey Stage

Results of applying the predictive model

Substantial parts of the Application Area around the existing mine and Olympic Dam village (60km²) were excluded from the survey because they had already been surveyed and/or disturbed by development (Figure 2). Another 25km² consists of the southern part of the Arid Recovery Reserve, an independent ecosystem restoration initiative (www.aridrecovery.org.au) which is excluded from the proposed expansion. The remainder,

515km², was surveyed thoroughly in 2007, 2008 and 2009 by teams of archaeologists and trainees from the three Aboriginal groups.

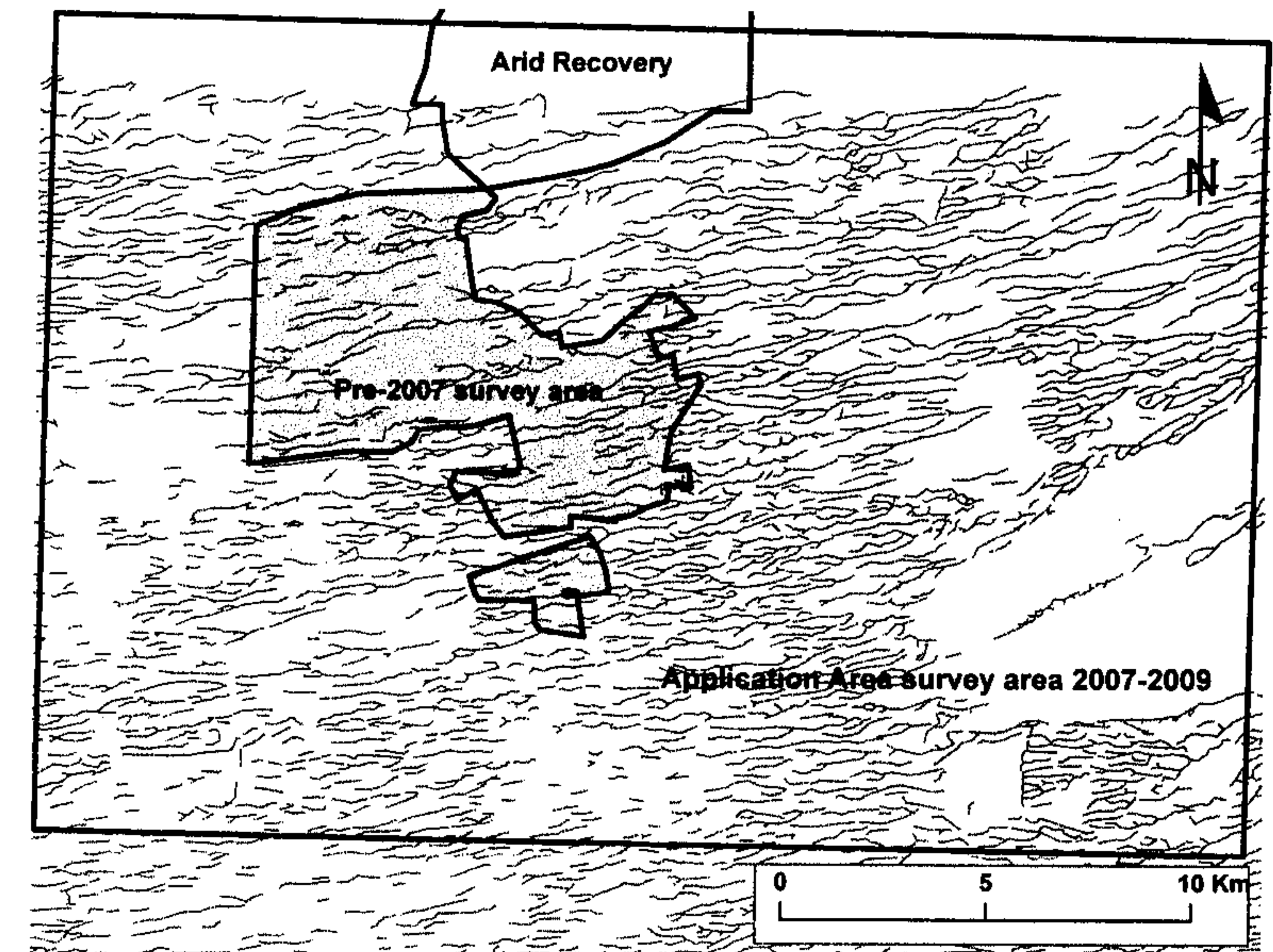


Figure 2 Olympic Dam showing areas archaeologically surveyed before 2007 and in 2007, 2008 and 2009.

Handheld computers running GIS software were used to record archaeological sites and to navigate while surveying. Over 16,000 archaeological sites were recorded at an average density of about 31/km². As in previous surveys, the main types of archaeological site recorded were stone artefact scatters (87%), artefact scatters with knapping floors (7%), knapping floors (5.5%) and quarries (0.5%). A brief description of these site types is presented in Box 1 and the characteristics of the artefacts scatters (94% of the total) are summarised in Tables 1 and 2 and Box 2.

Preliminary analysis of the data collected from 2007 to 2009 confirmed that the predictive model developed in 1981 has the capacity to forecast accurately the nature and distribution of archaeological sites across the range of landscapes which characterise the Application Area.

BOX 1 Archaeological site types at Olympic Dam

Quarries from which stone for flaked artefacts has been extracted. Quarries occur in the swales between dunes or on the gibber plains.

Surface scatters of stone artefacts where worked stone remains in the landscape. These sites contain mainly flaked stone artefacts (including implements such as backed artefacts, tulas, Pirri Points and other bifacial points) but also grindstones, hammerstones and anvils. It is common for them also to contain numerous unmodified blocks of stone, called manuports and occasionally clusters of hearth stones which are the remains of fireplaces. Most scatters of stone artefacts occur on sand dunes or sand sheets but some occur in the swales between dunes or, rarely, on the gibber plains.

Knapping floors which are discrete clusters of artefacts anywhere in the landscape (including at quarries) resulting from stone being worked at those locations. The criterion for a knapping floor is that the original block of stone largely can be reconstructed from the scattered pieces of flaked stone.

This can be illustrated by an example drawn from an analysis of some of the survey data taken from more than 4,000 sites recorded in 2007 and 2008 (Table 3). The model predicts that in dunefields with moderately closely-spaced dunes archaeological sites will occur much less frequently than in dunefields with widely-spaced dunes and will tend to be less rich. This reflects the less frequent occurrence of pans and outcrops of raw material in the former, due mainly to the increased cover of sand.

As predicted, sites occur much less frequently (are about half as common) amongst moderately closely-spaced dunes than amongst widely-spaced dunes. The frequency of occurrence of artefacts across moderately closely-spaced dunes is about an eighth (13%) of that across widely-spaced dunes showing, as predicted, sites in areas with moderately closely-spaced dunes are not only less frequent but are less 'rich' in terms of total numbers of artefacts.

Also as predicted, sites occur even less frequently amongst very closely-spaced dunes where no pans or exposed rock are found than in moderately closely-spaced dunes and the frequency of occurrence of artefacts is also much lower.

BOX 2 Large archaeological sites in the Application Area and surrounding region

In the Application Area most artefact scatters, knapping floors and quarries contain small numbers of stone artefacts. In the more than 10,000 sites recorded in 2007-2008 the average number of surface visible artefacts was 721 and the median only 20. Only a small proportion of sites contain more than 10,000 artefacts. In 2007-2008 only 90 such sites were recorded and these comprised 0.9% of the total.

Of the 665 sites recorded in the Application Area before 2007 only one was estimated to contain 100,000 or more surface visible artefacts. This represented 0.15% of the total.

By the end of the 2008 field season 12 sites with 100,000 or more artefacts had been recorded, representing 0.12% of the total of 10,491 recorded in 2007-2008. Hence the proportion of very large sites has barely changed over the 3 decades of archaeological site recording at Olympic Dam.

The largest site recorded during 2007-2008 was estimated to contain 750,000 artefacts and another four more than 500,000 artefacts. More than half of these 12 sites contained fewer than 200,000 artefacts.

Sites equally large and in some cases larger have been recorded during surveys in the region surrounding the Application Area. A brief description of four such sites is presented.

Site no./name	Density of artefacts (no./m ²)	Area (m ²)	Estimated no. of artefacts	Source and comment
<i>West of Olympic Dam</i>				
H184	100	3,600	360,000	Hughes 1981; Kinhill-Stearns Roger 1982
H203	100	80,000	800,000	Recorded during the reconnaissance survey undertaken to test the 1981 baseline archaeological predictive model
<i>Borefield Road Corridor</i>				
H408	60	3,300	200,000	Hiscock 1985; Hughes <i>et al.</i> 1982; Kinhill-Stearns Roger 1982
<i>Lake Eyre South</i>				
Rocky Creek	75	250,000	19 million	Hughes and Hiscock 2005

The model predicted that sites would occur infrequently in gibber plains, stony flat plateau surfaces, but that the sites that occur on them (quarries and knapping floors) would contain relatively large numbers of stone artefacts. The data for gibber plains (Table 3) support this prediction. The frequency of occurrence of sites in gibber plains is the lowest of all of the landform types yet the number of stone artefacts/km² is higher than in both moderately closely-spaced dunes and very closely-spaced dunes, reflecting the relatively large number of artefacts in the occasional quarry and knapping floor sites which are characteristic of gibber plains.

Table 3 Frequency of occurrence of archaeological sites and materials across different landforms.

	Landform			
	Widely-spaced dunes	Moderately closely-spaced dunes	Very closely-spaced dunes	Gibber plain
No. sites/km ²	44	23	9	5
No. artefacts/km ²	21,735	2,909	994	3,677

Archaeological patterns

One of the key findings from the intensive field surveys from 2007 to 2009 is that no new or anomalous site characteristics were observed, despite collecting data from more than 16,000 additional sites – a twenty-fold increase in the number recorded previously. Initial analysis of the survey database undertaken in 2008 and 2009 for BHP Billiton for their application for consent to disturb sites under the *Aboriginal Heritage Act 1979* demonstrated that the range of site areas, artefact densities, total assemblage sizes, and implement types and proportions recorded in 2007-2009 were all within the range observed previously, and were entirely consistent with the predictive model summarised in Tables 1 and 2 and Box 2. Furthermore, the location and density of sites recorded in 2007-2009 is consistent with patterns of site variation within and between

geological regimes and landform types observed in earlier surveys and anticipated in the model. The similarity of sites found in 2007-2009 with those recorded in the previous decades, and their conformity with the predictive model, is a result of the existence of strongly and clearly defined archaeological patterns across the region. In scientific terms these archaeological patterns display a high level of 'redundancy' in the sense that they are repeated over and over in comparable environmental contexts throughout the Application Area, and consequently the several hundred sites that were used to construct the predictive model in the 1982 Draft EIS (Tables 1 and 2) identified accurately the range of site locations and assemblage characteristics present over a wider area. Since a twenty-fold increase in the number of archaeological sites recorded in the three decades since work for the 1982 Draft EIS began has not yielded any archaeological sites that contradict the model, and since the number of archaeological sites recorded in the Application Area exceeds 16,000, it is concluded that the complete range of sites that exist within the Application Area have almost certainly been observed and characterised.

The existing archaeological record shows that this sizeable number of archaeological sites is only a tiny fraction of the total number of similar sites in the wider region. Regional surveys undertaken for the Olympic Dam project by Hughes and colleagues have shown that the same kinds of archaeological sites, in the same range of environmental settings, continue in a north-south direction from Port Augusta in the south to Lake Eyre in the north, over a distance of about 450km and over an area exceeding about 200km² (see Hughes and Hiscock 2005). Closer to the Olympic Dam mine, an area for which there is a good quantitative archaeological record, the landscapes and site types, sizes and densities are essentially the same as in the Application Area (see Box 2). It is estimated that at an average density of 31/km², there are about 250,000 archaeological sites of the kind recorded at Olympic Dam within a radius of 50km of the Special Mining Lease. This is an order of magnitude more sites than in the Application Area. Consequently a very large number and proportion of sites of the kind which exist in the Application Area will not be impacted by the expansion.

Consistent with the model, a substantial majority of archaeological sites within the Application Area represents the residues of short term occupation of the kind found throughout arid northeast South Australia, and arid Australia more generally. Large numbers of small sites containing assemblages with low richness in landscape contexts with no access to permanent water are typical archaeological signatures of mobile foragers, both in the region of Olympic Dam as well as in other arid zone contexts in Australia (e.g., Veth 1993, 2005). The assemblages contained in these sites have limited scientific value in terms of what they reveal about past human activity. Much of the value that they contain was documented in the course of the field recording.

There are, however, a small proportion of sites within the Application Area that have the potential to provide a much greater insight into past behaviours. These sites are deemed to be of high scientific value. Sites of this kind are not unique to the Application Area and are found in similar abundance and similar contexts throughout surrounding arid landscapes in northeast South Australia. Thus large numbers of sites of similar high scientific value in these surrounding landscapes will remain unaffected by the expansion of the Olympic Dam project.

The information that is contained in the sites identified as having high scientific value in the Application Area has not yet been fully documented by the field recording methods that were used during the survey stage. The value in these sites is their ability to contribute to the store of scientific knowledge about the archaeology of this region. Specifically these sites are ones that will be able to be dated and/or contain assemblages that are suitable for developing detailed behavioural inferences. Consequently further detailed investigations need to be undertaken on these sites of high scientific value, involving salvage and further recording and analysis. Where salvage work is undertaken, most (and in some cases all) of the artefacts from the sites are being removed, a process which will greatly diminish the scientific value of these locations. Once the additional studies have been undertaken, these sites of high scientific value can be disturbed along with the other sites occurring in the Application Area. The loss of these sites will be mitigated by the wealth of archaeological information that will be obtained through detailed recording and/or salvage of them.

Mitigation work involving salvage and further recording and analysis is incorporated in the Heritage Management Protocol.

The Salvage Program

The salvage program involves a number of actions including further recording of selected sites, collection of samples of archaeological assemblages, excavation, luminescence dating of sediments and potential hearth stones, cataloguing and collection management to museum standards, analyses of selected salvaged assemblages and reporting.

There has been on-going consultation about the salvage program with Aboriginal people who are parties to the Olympic Dam Agreement and they are also being provided with archaeological training and employment in the assessment and salvage of the sites.

Rationale for Additional Work on Known Sites

A fundamental rationale for additional work is to preserve samples of scientific value for the future. Material salvaged from sites is important as a permanent scientific record of the kinds of artefacts that were made and used in the study area. These artefacts will be preserved so that they are available for study by others, including Aboriginal people and researchers, who may pose different questions from those being addressed in the Olympic Dam archaeology program. Further study of samples of archaeological material from the Olympic Dam area will prove vital in completing a picture of prehistoric occupation of the region and testing/enhancing the predictive archaeological model.

The 2007-2009 survey yielded a large number of sites, and the records of site content that were obtained in the field characterised the location and approximate size and raw material composition of the artefact assemblages. These data are essential for examining spatial variations in land-use and reconstructing the patterns of ancient settlement in this desert region. The survey data methods were not designed to provide, and cannot provide information about other aspects of Aboriginal lifeways in these sites. There is a variety of aspects of technology and stone tool use which can be studied only by

different and more detailed examinations of the assemblages in the sites: the way blocks of stone are knapped initially at quarries and knapping floors, the kinds of objects (e.g., flakes/cores, large/small) that are transported from the material sources, the kinds of tools that are made on dunes after material has been brought there, the level of standardisation in the manufacturing process, the causes of variation in production, and the chronological differences in these activities. This information will clarify and explain the patterns of artefact assemblages observed during the survey and answer significant questions raised by those patterns. For example, the survey located several different kinds of backed artefacts (triangular, trapeze and crescents), sometimes they were found in the same sites, while on other occasions only one or two forms were represented. Sometimes these backed artefacts are the dominant implements in a site, on other occasions they are rare compared with tulas, points or other forms. Is this because they were made at different time periods, or from different materials, or for different functions or for other reasons? These illustrate some of the key questions that emerge from the archaeological survey, questions that go beyond the capacity of a model that predicts site occurrences, and answers to which will provide real information about past resource use in this environment.

In determining which sites warrant further study, and the total number of sites on which such work is to be carried out, a number of principles have been employed:

- Sites threatened by proposed development are considered to have higher priority for salvage than sites that are not endangered;
- A diversity of sites needs to be studied to reflect the range of ancient activities. For instance, quarries, multiple knapping floors and single knapping floors probably represent a range of different scales of raw material extraction and working. The nature of activities represented at these sites probably differs, although survey data do not provide information on the character of those differences;

- A number of sites need to be investigated to characterise the different time periods represented by human occupation in the region. No single site is expected to contain occupation from all times during the thousands of years humans occupied the Olympic Dam area, and several sites need to be excavated to develop information about the chronology of occupation;
- Sites from the whole of the large range of different landscapes (or terrain patterns) are required to express the dissimilar archaeological signatures and settlement patterns that have been documented by surveys;
- A variety of sites is necessary to measure the varied patterns of implement production (such as points, backed artefacts of different forms, tulas and 'amorphous retouch') and the articulation of these manufacturing systems with different raw materials and site functions;
- Functional differences between sites will be assessed more effectively if further work focuses on suites of comparatively close sites which are likely to be part of the same local economic and technological system. Hence where possible the salvage program will exploit the analytical benefit of selecting sites that represent functional clusters within the landscape; and
- The sites with the most potential for these scientific investigations are those with high chronological and spatial resolution. Typically such sites have low levels of disturbance through erosion/deflation and high chronological detail, either because the archaeological material is a consequence of brief activities (such as knapping a single boulder) or is separated from material of other time periods (such as different layers in a dune).

As a result of the application of these principles about 150 sites grouped into 16 'clusters' were identified for further work (Figure 3).

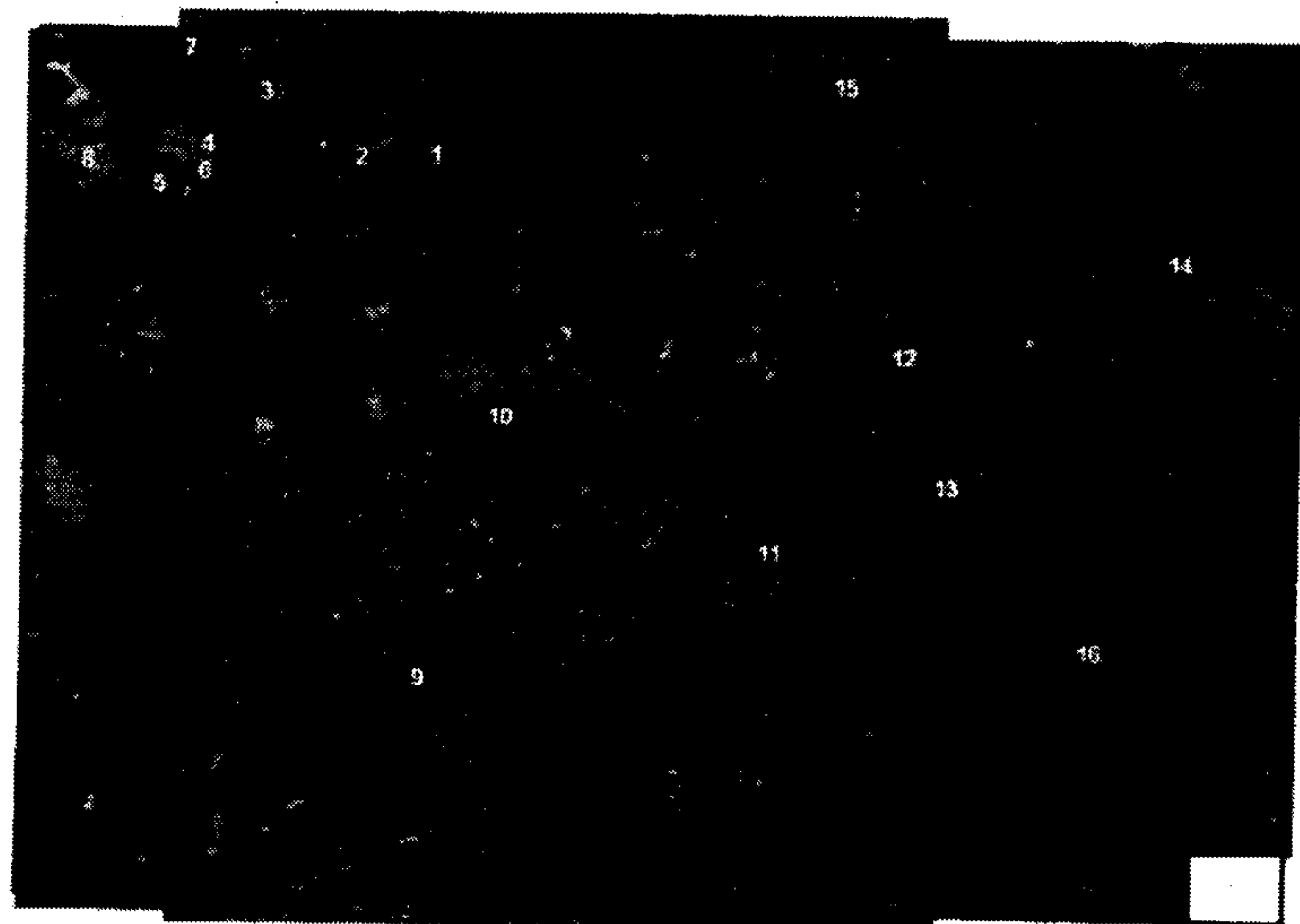


Figure 3 Olympic Dam showing the Application Area (black), the existing Special Mining Lease (mauve) and the 16 'clusters' containing the sites to be salvaged.

The salvage program based on the survey results and these principles commenced in mid-2010. By the end of that year about 40 sites of various types had been collected/excavated and logged in a systematic acquisition database and cataloguing of collections to museum standards had commenced. When salvage, acquisition and cataloguing are at an advanced stage detailed analyses will be undertaken on selected samples of the collections and the findings published.

An additional benefit of the work carried out in this project is the archaeological training and public education that is embedded within it. A PhD student is already working on chert and quartzite knapping floors and other research projects are being planned. One representative each from the three Aboriginal claimant groups is working full-time on the project and has received training to the point they are now all competent field archaeological assistants. Furthermore, for a month in 2010 the Olympic Dam archaeology project team hosted the University of Washington Australian Desert Archaeology Field School involving 10 undergraduate students and two staff. Numerous visitors from BHP Billiton and the

Aboriginal communities have come to see the program in action and the profile of archaeology is being raised within the local Roxby Downs community and more broadly.

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